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ADDRESS

OF

PROF. H. A. NEWTON,*

VICE PRESIDENT FOR SECTION A.

MEMBERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:

I THANK you heartily for the honor you have done me in calling me to preside over this section.

The first of the subjects named as belonging to section A, is mathematics. In the few words I shall say, I wish to ask for that branch the real primacy which has thus in form been given to it. I plead for more study of mathematics by American men of science.

I do not speak of its place in education. Whatever interest we may have in schemes of education, we are not discussing them here. That there has been, and is, a notable lack in the amount of American contributions to mathematics has been so fully shown by my predecessor in this office in a recent number of a leading review, that I need not repeat the story.

It is not, perhaps, to be wondered at that in a new country its flora and fauna, its physical and geological features, should have more attraction at first than the exact sciences. Then, too, there have been in this country large rewards to labor, especially to

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skilled labor. Livings and prizes have enticed men to work where practical results are directly in view, in the applied rather than in the pure mathematics.

But whether these reasons or others have caused it, the unpleasant fact is that the American contributions to the science of quantity have not been large. Three or four volumes, a dozen memoirs, and here and there a fruitful idea having been selected from them, there is left very little that the world will care much to remember. I refer, of course, to additions to our knowledge, not to the orderly arrangement of it. To make first-rate text-books, or manuals, or treatises, is a work of no mean order, and I would not underestimate it. In good mathematical text-books we need not fear comparison with any nation. But so few additions have been made to our knowledge of quantity, that I fear that the idea has been quite general among us that the mathematics is a finished science, or at least a stationary one, and that it has few fertile fields inviting labor, and few untrodden regions to be explored. Hence many bright minds, capable of good work, have acted as though the arithmetic, the algebra, and the mechanics which they studied covered all that is known of the science. Instead of going on in some path out to the bounds of knowledge, as they had perhaps the ability to do, they dug in the beaten highways, and with care planted seed there, hoping for fruit. How much such ill-directed thought has been spent on the theory of numbers, on higher equations, on the theory of the tides, &c., which if rightly expended on some untrodden though humble field of the science, might have added really to human knowledge! And yet hardly any science can show on the whole a more steady progress, year by year, for the last fifty years, or a larger and healthier growth, than the science of quantity. Here too, as in every other science, the larger the field that has been acquired, the longer its boundary line from which laborers may work out into the region beyond.

An individual may wisely neglect one science, in order to work in another. But a nation may not. For the healthy growth of all, each science should be fostered in its due proportion. But the mathematics has such relations with other branches, that neglect of it must work in time wider injury, I believe, to the cause of science, than neglect of any other branch. I will give a few reasons for this belief.

First, I appeal to your experience. Am I wrong in supposing that

each of you has, at one time or another, been arrested by lack of sufficient knowledge of the mathematics in a line of research that seemed promising? Would not each of you join me in urging a young student in almost any branch of science to acquire first of all such a knowledge of geometry, analysis, and mechanics, that the main ideas in them shall ever be familiar to him, and their processes at need be easily recalled? Certainly so often has the regret of a want of such knowledge been expressed to me by successful men of science, that I have little doubt of your answer.

Again, I argue from a natural law of succession of the steps of discovery in the exact sciences. We first see differences in things apparently alike, or likeness in things apparently diverse, or we find a new mode of action, or some new relation supposed to be that of cause and effect, or we discover some other new fact or quality. We frame hypotheses, measure the quantities involved, and discuss by mathematics the relations of those quantities. The proof or disproof of the hypotheses, most frequently depends upon the agreement or discordance of the quantities. To discover the new facts and qualities has sometimes been thought to be higher work than to discuss quantities, and perhaps it is. But at least quantitative analysis follows qualitative. It is after we have learned *what kind* that we begin to ask *how much*. The investigator is lame if he is not prepared to follow up the discovered relations of the quantities.

Again, throughout the sciences of this section, the laws are more and more assuming a mathematical form. In physics I need hardly mention the increasing rule which rational mechanics is acquiring in reducing classes of phenomena to varieties of forces and motions. In chemistry, mathematical laws must govern the combinations of the elements, both in the processes and in the results of chemical union. Though we may not now explain chemical action as one branch of mechanics, yet the mathematical sciences of heat and light cannot be made complete without extending mathematics over large provinces in chemistry. Even in the sciences of section B, the mechanical and other quantitative ideas are gaining a sure place.

The unwisdom of neglecting the mathematics is again seen by considering some of the problems, which appear to be in their nature capable of a mathematical solution. To explain by the accepted laws of rational mechanics all the forces and motions of the

ultimate particles of matter, of inorganic matter even, may very well be beyond the powers of the human mind. But that some of those forces and motions will be explained, even at an early day, seems to be almost certain. So the essential differences in the chemical elements may not be beyond discovery and explanation. Each line in the spectrum has its definite place, and those places are the results of certain laws of structure of the substance that gives the spectrum, and of its consequent action upon the light that comes from or traverses the substance. The time seems near for a Kepler who shall formulate those laws, and for a Principia which shall unite them in their most general mathematical expression. In like manner along the line that in astronomy and physics separates the unknown from the known, there are hundreds of questions whose solution, if they are to be solved at all, must be in part mathematical.

It is with some hesitation that I leave the more familiar ground of this section and speak of the laws of quantity in the other sciences. But there is good reason apparent to even the outside observer, for the belief that the mathematics will in the future (of course, in some cases, the very distant future) have much to do in fields from which it is now very properly shut out. Indirectly, through physics, it has already a foothold in some of them.

Political economy is in its ultimate nature a branch of applied mathematics, and even in its present condition we are entitled to distrust the guidance in it of one who has not clear conceptions of the relations of quantity. In fact, most of the questions in social science seem to have a two-fold character, the one moral, and the other mathematical. In geology how many problems are rising into importance whose solution depends upon mathematics! The geometry of animal and vegetable forms is a subject as yet almost untouched by the mathematician. Yet in the nature of the case each form is the result of definite forces, and similarity and law in the forms represent like properties in the forces producing them.

There is, moreover, a large possible field of applied mathematics in the science that shall explain the relations between the facts of the outside world and the impressions which they make through the organs of sense on the mind. The Greeks solved practically one of its problems when they made the lines of the Parthenon curved that they might appear straight. Another is met by the astronomer when he has to apply to his own observations a personal

equation. When we can explain the correction which one color needs because of its nearness to another color, we may perhaps have more hope of applying to color a unit of measure, and so treating of its quantity. Music has its mathematical basis, and differences in sounds have submitted to analysis and measurement. The physiological theories of vision and hearing must, as they develop by experiment, furnish many problems to be solved by mathematics.

Even in the sciences beyond the domain of this Association there is some evidence of the sovereignty of number and measure. Some of those who have most thoroughly studied the theory of the beautiful, believe that mathematical laws will yet be found to lie at the basis of that theory. The recognition of a more and a less in all our mental powers, impressions, and actions; of a law of obedience to the strongest motive; of an inseparable connection of the greatest good with right moral action; what are these but the indications of the existence of quantitative laws in mental and moral sciences?

That there is a growing conviction that mathematical relations run through all subjects of thought is proved by the increasing use of the word *force*. Men speak of vital forces, mental forces, moral forces, social forces, force of will, force of passions, of affections, of appetites, force of words, force of public opinion, force of conscience, force of character, and so on, through all the range of thought. The word force can hardly be used, even as a metaphor, without implying, to some extent, the idea of a cause and an effect, each possessing the attribute of quantity, and each related quantitatively to the other, though we cannot in our present ignorance measure the one or the other.

Is all this a mere fancy, or a day-dream of the imagination, rather than a sober conception of science fitted to this occasion? If it so seems to you, look at the actual history of one kind of quantity, that of probability. Quantity of probability differs from most kinds of quantities, in that it is an impression on the mind that has no necessary correspondence with the facts of the outside world. It is, to use the mathematical term, a function of finite knowledge, depending for its magnitude entirely upon what we know, or think we know, changing with every accession of knowledge, real or supposed, becoming certainty in the presence of full knowledge, and having no existence where there is no knowledge at all.

This mental impression of the more and the less probable mathematicians learned to measure. Its theory was first applied to simple games of chance, but it has grown in these two hundred years until it is now the firm basis on which rest pecuniary contracts for many thousands of millions of dollars in insurance. It guides and controls, by the method of least squares, approximate measurements in all branches of exact knowledge, and going over into mental science requires logic to be rebuilt from the bottom.

Has the thought arisen in any of your minds that this idea of a possible extension of the science of quantity is derogatory to those other sciences over whose domains it may some time claim a qualified sovereignity—that it puts the good and the beautiful even alongside of the masses which we weigh and the bulks which we measure? Pure mathematics is not a science of matter. It is a mental science, dealing solely with mental conceptions. I am inclined to accept Prof. Peirce's extension and definition of it, that it is the science that draws necessary conclusions. But however we may extend or limit the science, it expresses necessary laws of our thinking, and it is not derogatory therefore to our highest knowledge that it is made subject to it. Moreover, our conceptions of the Creator become higher, as we are led on by our studies to emphasize the words of the Hebrew wise man, "Thou hast put together *all things* in measure, and in number, and in weight."